RR Lyrae Variables in Globular Clusters and the Second-Parameter Phenomenon

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Abstract. We propose to use RR Lyrae variables in globular clusters (GC's) to probe the origin of the second-parameter phenomenon.

1. Introduction

Until recently, the view that age is the second parameter of horizontal-branch (HB) morphology has been widely accepted. Recent developments suggest, however, a much more complicated scheme where several parameters may be playing important rôles (Stetson, VandenBerg, & Bolte 1996; Ferraro et al. 1997; etc.).

Second-parameter candidates can be divided into two categories: those which do *not* affect the HB luminosity (age, mass loss on the red giant branch), and those which *do* (envelope helium abundance Y, core mass at helium-flash). *We thus propose to use RR Lyrae variables, whose properties are strongly sensitive to the HB luminosity (e.g., van Albada & Baker 1971), as a vertical diagnostic of the HB morphology.*

2. Approach to the Problem

The determination of RR Lyrae "equilibrium temperatures" ($T_{\rm eq}$) relies on the transformation of mean colors into temperatures (e.g., Sandage 1990; Carney, Storm, & Jones 1992, CSJ92). CSJ92 demonstrated the existence of a tight relationship involving $T_{\rm eq}$, periods, blue amplitudes (A_B), and metallicity [Fe/H] for field RR Lyraes. We have rederived the CSJ92 relationship from data in their Table 4, but using the latest [Fe/H] values from Layden (1994). Stars SS Leo and TT Lyn were excluded from the fit, due to their poorly determined parameters.

To our surprise, we discovered that the period term in the $T_{\rm eq}$–period–A_B–[Fe/H] relationship does *not* lead to a significant reduction in the residuals to justify its inclusion. In fact, *determining temperatures from the periods may easily mask the effects of luminosity variations upon cluster-to-cluster period shifts, and should thus be avoided whenever possible.* Our new relationship reads:

$$\frac{5040}{T_{\rm eq}({\rm K})} = (0.850 \pm 0.013) - (0.073 \pm 0.008)\, A_B - (0.010 \pm 0.003)\, [{\rm Fe/H}]. \quad (1)$$

This relationship provides an excellent match to the CSJ92 temperatures. The rms deviation is only 56.9 K, compared with 54 K from eq. (16) in CSJ92 (which does include a period term).

3. Applications to Globular Clusters

Assuming eq. (1) to be also valid for GC RR Lyraes, we have computed temperatures and measured the "period shifts" $\Delta \log P$ at fixed $T_{\rm eq}$ with respect to the "reference" cluster M3, for ab-type RR Lyraes in a set of 34 GC's. Blazhko variables were avoided. Our main findings may be summarized as follows: a) Clusters with similar metallicity may present significantly different $\Delta \log P$ values (e.g., NGC 6171 vs. NGC 6712); b) The bimodal-HB GC NGC 1851 shows very large $\Delta \log P$'s (and also *very* high A_B's), the opposite occuring in NGC 6229 (which also has a bimodal HB); c) Among the Oosterhoff type II (OoII) GC's, we find a range in $\Delta \log P$'s, with a mild correlation with HB type (which however can be almost entirely ascribed to NGC 5986); d) In the mean, OoII GC's do not show very large $\Delta \log P$'s; e) The RR Lyrae variables in the metal-rich clusters 47 Tuc and NGC 6388 have very large $\Delta \log P$'s; f) ω Cen variables have large $\Delta \log P$'s, but a detailed analysis of the correlation between $\Delta \log P$ and [Fe/H] in this cluster must await the resolution of the discrepant [Fe/H] distributions found for its giants and RR Lyraes (Suntzeff & Kraft 1996).

4. A Caveat

Possible helium abundance differences between field and GC RR Lyraes (Sweigart 1997) may have to be further investigated, as far as the period-shift effect is concerned. In particular, from Marconi's (1997) models, we find that *M15 variables lie in the region of the $A_B - T_{\rm eq}$ plane most affected by Y, whereas the M3 ones fall mostly in the region not sensitive to Y.*

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New Possible Variables in the Outer-Halo Globular Cluster Palomar 3

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Abstract. We present a list of ten possible variable stars in the globular cluster Pal 3. Seven are new suspected variables. The variability of the RR Lyr candidate reported by Burbidge & Sandage (1958), as well as of the Pop. II Cepheid and RR Lyr from Gratton & Ortolani (1984), are confirmed.

1. Introduction

The limited number of variability studies for the outer-halo globular cluster Pal 3 (Burbidge & Sandage 1958, BS58; Gratton & Ortolani 1984, GO84) has prompted us to undertake a new survey for short-period variables. Special motivation for our study was provided by the possible presence of a Pop. II Cepheid in such a red-HB cluster (GO84). As well known, Pop. II Cepheids are usually found in clusters with blue-HB tails only (e.g., Smith & Wehlau 1985).

2. Observations and data reduction

Our analysis was based on 35 V and I CCD frames obtained on 3 nights at the 1.54m telescope operated by Steward Observatory, University of Arizona, and at the 2m telescope of NAO "Rozhen" (Bulgaria). The photometric reductions were carried out using the DAOPHOT package available in IRAF. The instrumental magnitudes were transformed to the standard VI system.

3. Results

Using the variability search techniques of Welch & Stetson (1993) and Kadla & Gerashchenko (1982), comparison of the brightness and night-to-night variations of the stars, and light curve analysis, we reached the following conclusions:

1. We confirm the variability of the RR Lyr star candidate from BS58;
2. We confirm the variability of the Pop. II Cepheid and the RR Lyr star (No. 185) suspected by GO84;
3. We find seven new variable star candidates (cf. Table 1);
4. Stars V1, V2, V9 and V10 show variability according to all variability criteria, and are thus very likely to be true variable stars. V1, V2 and V10 are probable ab-type RR Lyr stars (according to the light curve analysis), while V9 is probably a red variable;
5. Stars V3, V4 and V5 satisfied only some of the variability criteria, and their status remains uncertain.

Unfortunately, our small number of CCD frames and irregular time intervals did not permit us to obtain representative light curves and periods. The limited data allow only to estimate a preliminary period $P = 0.47$ days for V2.

The x and y coordinates in Sawyer-Hogg's (1973) catalog system and the estimated mean V magnitudes of candidate variable stars are given in Table 1.

Table 1. Mean V magnitudes for candidate variable stars in Pal 3

				JD 244+	
			50465.59	50467.53	50490.54
Name	x (arcsec)	y (arcsec)	V	V	V
V1	−3.2	−2.3	21.06	20.38	20.27
V2	15.6	4.1	20.22	20.62	20.73
V3	−57.7	14.0	20.26	20.56	20.34
V4	25.6	18.6	20.45	20.44	20.61
V5	−60.7	35.0	20.48	20.48	20.62
BS58	−29.2	−4.8	20.25	20.66	20.25
No. 155	−0.8	4.4	20.82	20.71	20.62
Pop. II Cep.	18.6	17.0	19.26	19.41	19.44
V9	−8.2	0.3	18.63	18.70	18.72
V10	−42.4	−5.9	20.13	20.54	20.44

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On the Production of Bright RR Lyrae Variables in Metal-Rich Globular Clusters

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1. Second Parameter Effect in NGC 6388 and NGC 6441

Recent HST observations have revealed that the metal-rich globular clusters (GC's) NGC 6388 and NGC 6441 contain an unexpected population of hot horizontal-branch (HB) stars and therefore exhibit the well-known second parameter effect (Rich et al. 1997). Most surprisingly, the HB's of these clusters have a pronounced upward slope with decreasing $B - V$, with the mean HB luminosity at the top of the blue tail being roughly 0.5 mag brighter in V than the well-populated red clump, which itself also slopes upward. Differential reddening is not the cause of these sloped HB's (Piotto et al. 1997).

The second parameter effect has often been attributed to differences in age or mass loss on the red-giant branch (RGB). However, canonical simulations show that increasing the assumed age or RGB mass loss will move an HB star blueward, but will *not* increase a star's luminosity (Fig. 1a). This indicates that the blue HB population in NGC 6388 and NGC 6441 does not arise from either an older cluster age or greater mass loss. Something else must be affecting the HB morphology in these two clusters. *Nature may therefore be giving us an important clue for understanding the origin of the second parameter effect.*

We have begun an extensive theoretical study to determine the cause of the sloped HB's in NGC 6388 and NGC 6441. Three scenarios are being studied:

- A high cluster helium abundance scenario, where the HB morphology is determined by long blue evolutionary loops;
- A rotation scenario, where the core mass in the HB models is increased by internal rotation during the RGB phase;
- A helium-mixing scenario, where deep mixing on the RGB enhances the envelope helium abundance (Sweigart 1997).

We have found that all three of these scenarios predict sloped HB's (e.g., Fig. 1b) with anomalously bright RR Lyrae variables. This prediction is consistent with the long pulsation periods of the two known RRab Lyrae variables in NGC 6388 (Silbermann et al. 1994), as demonstrated in Fig. 1c. If confirmed, these scenarios would have important implications for stellar evolution and for the use of HB stars as standard candles to determine GC distances and ages.

Our full poster paper can be found at `astro-ph/9708174`.

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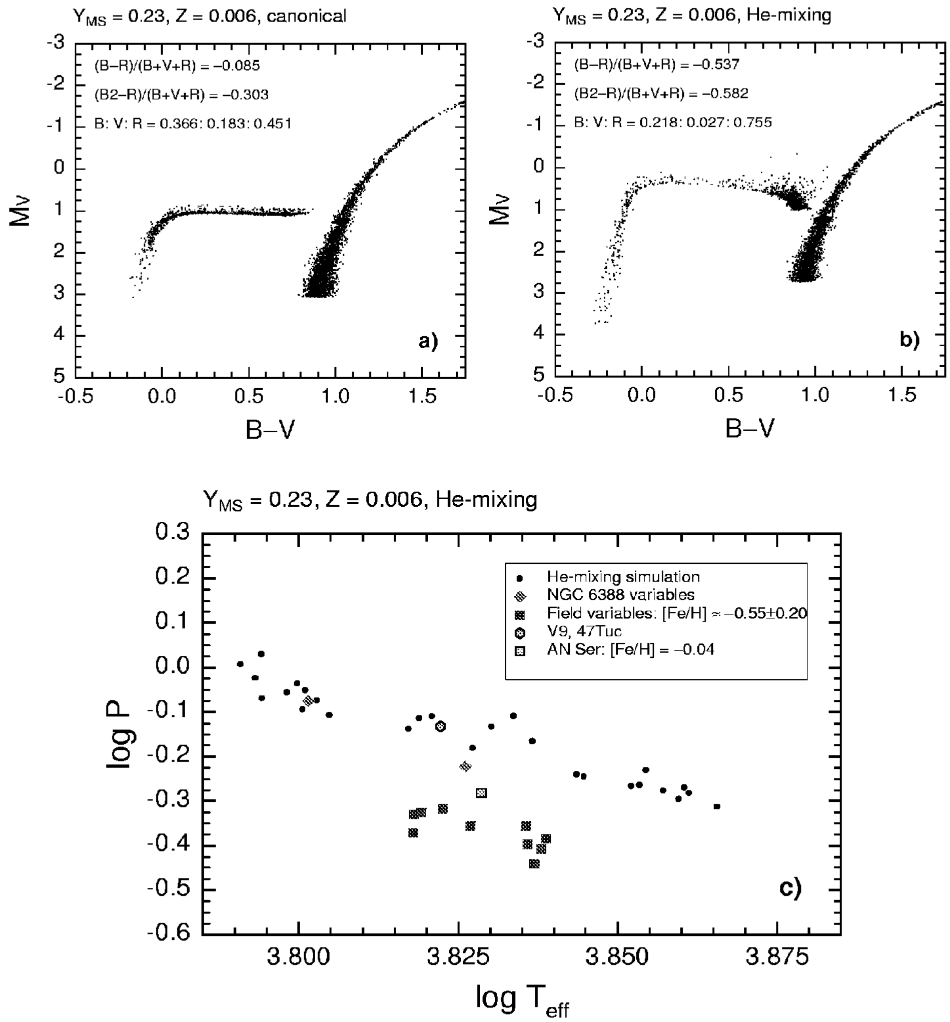

Figure 1. “Canonical” HB simulation (panel a), compared to a non-canonical one with an HB slope similar to that in NGC 6388 and NGC 6441 (panel b). The pulsation properties for this non-canonical case are compared to the observational data in panel c. Temperatures have been derived as described by Catelan, Sweigart, & Borissova (1998).

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